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DETERMINATION OF INTENSITY OF RADIOACTIVE CONTAMINATION IN THE OCEAN BASED ON THE NEW DATA OF EXCHANGE PROCESS.

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1. INTRODUCTION.

Numerous works encountered in scientific literature of recent years show that some authors are very much interested in the problem of evaluation of spreading rate of radioactive contamination in seas and oceans. It is known that this question requires profound knowledge of intensity of processes of the water mass mixing. Inverse problems are also known, that is application of data of radioisotope distribution with depth for determination of intensity of mixing. In them conclusion of intensity of process of mixing made is based on the analysis of the vertical distribution of radioisotopes deposited on the surface layer of the ocean after nuclear weapon tests (as a result of fall- out, in general, of stratospheric character). Some investigators use for this purpose data of distribution of the natural radioactive elements of cosmogonical origin, such as T, C-14, Be-7.

In the first case the term " age " was introduced to evaluate intensity process of spreading of radioactive contamination. Later this term was broadly used by various investigators for solving some practical problems. Those investigators who studied radiocarbon distribution in ocean waters determined the age of the Atlantic Ocean to be about 500 years. For the Pacific Ocean this value is 1500 years. Taking into account such great values of the age residence time of the fall-out radioactive products in the upper mixed layer was determined as 30-100 years.

Bowem and Sugihara / 1 / are believed to be the first to receive experimental data, which disproved such meaning of the intensity of deep water contamination in the ocean .

In 1957 they discovered penetration of radionuclides to the depth of 1000 m. The age of these radionuclides could not be greater than three years, because the intensive fall-out of radioactive isotopes began after 1954. Further observations carried out by Miyake and others /2/ confirmed the considerable penetration of radioactive Cs and Sr to much greater depths in the ocean. Thus the results of analysis of radioactive isotope distribution in the ocean show that values obtained by radiocarbon technique are wrong. In fact, the term "age" (though succesful in geology) could not be mechanically transferred to ocean waters and its usage supposing that the ocean waters did not mix and were stable - was wrong.

Rocco and Broecker noting many contradictions which could be encountered in modern knowledges of processes of the vertical radioactivity transfer tried to make a control experiment. But they received little material and it differed from the well corroborated knowledges of concentrations of radioactive Sr and Cs at intermediate and great depths in the ocean. As so, it is necessary to make some additional experiments and to analyse the obtained data with great care.

On the other hand it exists now the intensity of vertical mixing using data of radioisotope distribution which is in many cases based on Fikkian equation of diffusion. Some works are known now in which the authors made an attempt to calculate by indirect method values of turbulent diffusivity in the ocean evaluating intensity of the vertical transfer some simplifying suppositions were made. In particular, turbulent diffusivity was considered to be constant at various depths and seasons, and the vertical component of current velocity in the ocean was not taken into account. (Miyake and others-2 and Sereda-4). Naturally only qualitative values were received as a result, but they showed much higher intensity of process of mixing in the ocean, than it followed the determination of age by radiocarbon.

765

The quantitative discription of process of spreading of radioactive contamination with stationary flow on the surface layer of the ocean(which shows contents of radioactive fall-out) is given in this paper .For the analytical solution the authors had to schematise the problem showing ocean as a three-layered model with various laws of turbulent diffusivity distribution and vertical components of current velocities in every layer .Till now quite sufficient scheme of spreading of radioactive contamination in the ocean was not received, that is why the following work was performed by us :

1. During the r/v " Mikhail Lomonosov " cruises distribution of splinter products, deposited on the ocean surface from the atmosphere has been studied.

2. The vertical turbulent diffusivity values and vertical components of the average current velocities were calculated by technique given in the paper by A.G.Kolesnikov. These calculations were based on measurement data of three fields- velocity of current, temperature and salinity, also obtained during expeditions aboard the r/v "M.Lomonosov ".

3. The problem of finding spreading rate of radioactive contamination in the ocean was solved with the help of electronic computer .This solution was based on the obtained turbulent diffusivity data and current velocity data not considering any simplifying suppositions. Present paper is devoted to basic results of this work .

§ 2.THE r/v " MIKHAIL LOMONOSOV " OBSERVATIONAL DATA .

During recent years constant determinations of radionuclide contents in the ocean were performed aboard the research vessel of the Marine Hydrophysical Institute of the Academy of Sciences of the UkSSR. Investigations were carried out both for surface watersand deep waters. The obtained samples were processed according to standard

technique , including carbonate precipitation with fur - ther determination of radioactive Sr concentration by daughter yttrium-90. Carbonate precipitation of Sr-90 from 100-130 litre samples was made directly during expe - dition and received concentrated product was further pro - cessed under stationary conditions .

Radio-chemical processing of concentrated material was in a large measure performed by scientific group under the leadership of professor V.P. Shvedov and candidate of Physical and Mathematical Science L.I. Gedeonov to whom authors are grateful . It was considered that con- tents of stable isotope of Sr with salinity 35 ‰ are 13 mg/ kg . It is natural that it varied depending on sali- nity and conditional density . As denoted contents of stable isotope are not sufficient a portion of non- radio - active Sr- as salt $SrCl_2$ - was added to the sample for the reliable precipitation with carrier. 750 g of murriate of ammonium and 1200 g of anhydrous sodium carbonate was added to the solution as a poiser in order to prevent magnesium precipitation. Sr output was controlled by flame- photometric method . Then Sr precipitated as strontium nitrate. Sediment of strontium nitrate was centrifuged, and radioactive Sr contents were determined by daughter Yttrium. The vast areas of the Atlantic Ocean (40-50 N to 10 S) were studied . Considerable penetration of ra - dioactive Sr can be traced at maximum depths , where de- terminations of this radioactive isotope were made . And it is characteristic of all measurements made . Radio - active Sr concentrations oscillated in different areas from 0,05 (region of rise of deep water near Dakar) to 0,13 pico-curie . That is in good agreement with data pub- lished previously. Lowering of activity to 0,02 - 0,05 pico-curie can be noted in thermocline(See fig. 2). 1000 m lower to thermocline no abatement of specific acti- vity is noticed .

§3. Calculation of penetration of radioactive contamination to depth.

The problem of vertical penetration of radioactive material

766

C concentration in the ocean can be given in the following equation:

$$\frac{\partial c}{\partial \tau} + W(z,\tau)\frac{\partial c}{\partial z} = \frac{\partial}{\partial z}\left(\mathcal{D}(z,\tau)\frac{\partial c}{\partial z}\right) - \lambda c, \quad /1/$$

with boundary conditions

$$c = c_o(\tau) \quad \text{with } z = 0 \qquad /2/$$

$$\mathcal{D}\frac{\partial c}{\partial z} = 0 \quad \text{with } z = H \qquad /3/$$

where τ is time, z is vertical co-ordinate (axis z directed vertically down, it originates from the ocean surface . W (z,τ)- is vertical component of the average velocity of current , D (z,τ)- is turbulent diffusivity , $T_{1/2}$ is half-life of radioactive material, H - ocean depth,

$$\lambda = \frac{0{,}693}{T_{1/2}}$$

Function C_o (τ), describing value of radioactive isotope concentration on the surface was built using data obtained aboard the r/v " Mikhail Lomonosov " by measuring the real contents of concentrations of radioactive material in the surface layer .

W and D values were computed using the actual data of measurements of current velocity , temperature and sali - nity carried out on board the r/v " M. Lomonosov " and also Fuglister ' s data atlas (7) by technique given in the paper (6) The obtained W and D values were analysed and generalized by us and typical profiles of change of these values were drawn in accordance with depth and seasons (see fig.1). Seasonal run of W and D variation with depth in the scheme accepted by us , corresponds to the following values of thermocline depth according to months of the year;

XII, I, II / Winter /-200 m.
III, IV, V / Spring / -60 m.
VI, VII, VIII / Summer /- 90 m.
XI, X, IX / Autumn / -150 m.

766

Having determined C_0, D and W aspect , the solution of problems /1/ — /3 / was made by electronic computer (by numerical method).
Computation involved period of time from 1954 to 1964. An example of such calculation of spreading of Sr-90 concentration ($T_{1/2}$ = 20 years / is given in fig.2 (curve 1). This distribution of Sr -90 concentration with depth is refered to 4-th quarter of 1962. Data of Sr-90 concentration obtained during the r/v " Mikhail Lomonosov " expedition can be also refered to this period. They are given in fig.2. Theoretical and actual C values for Sr -90 are in good agreement to depth of 1000 m.
An essential effect of seasonal variation of thermocline depth on penetration of radioactive material from surface to deep water layers was revealed. It is known that minimum D values are found in lower border of thermocline . But directly under it ascending motions of water are traced . Under such conditions blocking layer arises. Penetration of concentration lower to this layer is difficult of access. But if thermocline is lowering , concentration of material is lowering together with it, and is distributed nearly uniformly over it . After the rise of thermocline, concentration of material (which was lowered together with it) is found lower to it under conditions of marked values of turbulent diffusivity by the vertical line D. Under these conditions the considered part of the material penetrates further to deep water layers . Thus variations of thermocline depth effect like a sluice, when concentration of radioactive material spreads from surface layer to depth . Such an effect of thermocline fluctuations is of great importance in exchange of various properties between surface layer and deep water layers . In order to estimate the effect of seasonal variations of thermocline depths on penetration of radio - active material to depth we calculated it under the same conditions as for curve 1, in fig.2. But D and W are independent of time, that is for the permanent depth of thermocline .

766

The result of this calculation is shown as curve 2 in fig.2. As it is guven in fig.2 specific activity values with variation of thermocline on the surface are twice less than at fixed profiles D and W.

§ 4. Conolusion.

Good agreement between actual and calculated concentrations shows the correctness of choice of initial suppositions. This circumstance allows us to detail a number of peculiarities of process of vertical spreading of radio - active material in the ocean. In particalat, analysis of the given solution indicates that depth of penetration of radioactive isotapes increases with the growth of half - life of radioactive isotope. Then we succeded in finding mechanism of spreading of isotope concentration in sur - face layer caused by seasonal variations of thermocline depth, which creates the blocking layer. As it turned out the vertical transference of thermocline depth effects like a sluice letting radioactive material from surface layer in to deep-water layers. All this leads to much higher intensity of exchange than at permanent depth of thermocline. As a result the performed calculation fulfilled for ten year period indicates that during this period radioactive material from surface layer reached the bottom to depth of 5000 m, and consequently, it has much higher rates of spreading than according to "age".

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766

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INSCRIPTIONS TO FIGURES.

Fig.1. Seasonal run of D and W variation with depth.
Fig.2. Distribution of Sr -90 concentration with depth at changing depth of thermocline (curve -1) and at permanent depth of thermocline (curve -2)

766

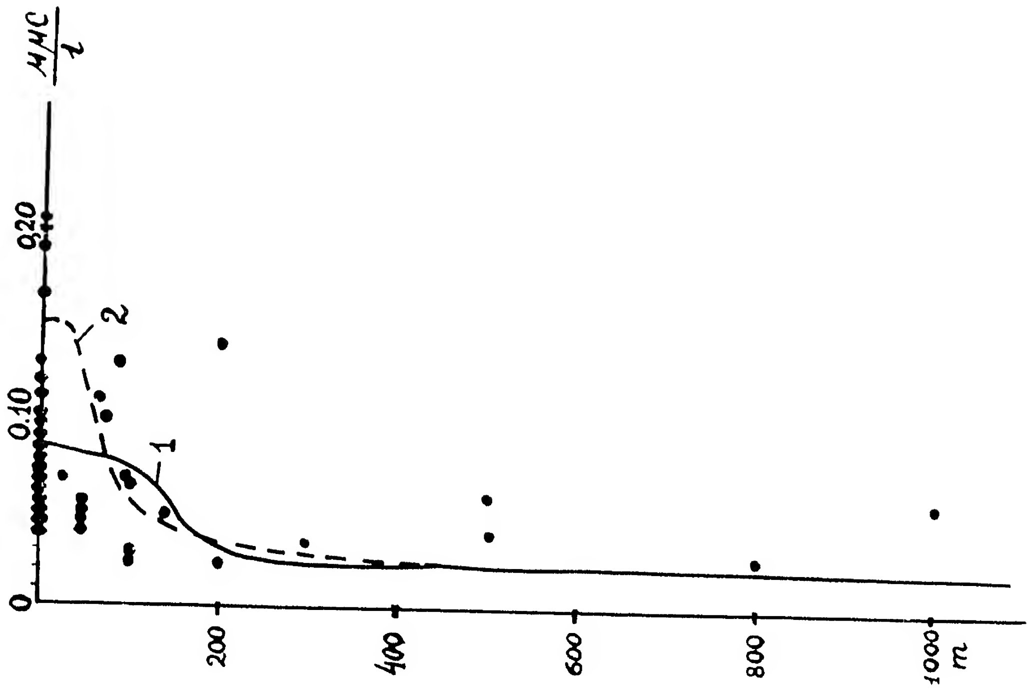

Fig. 2

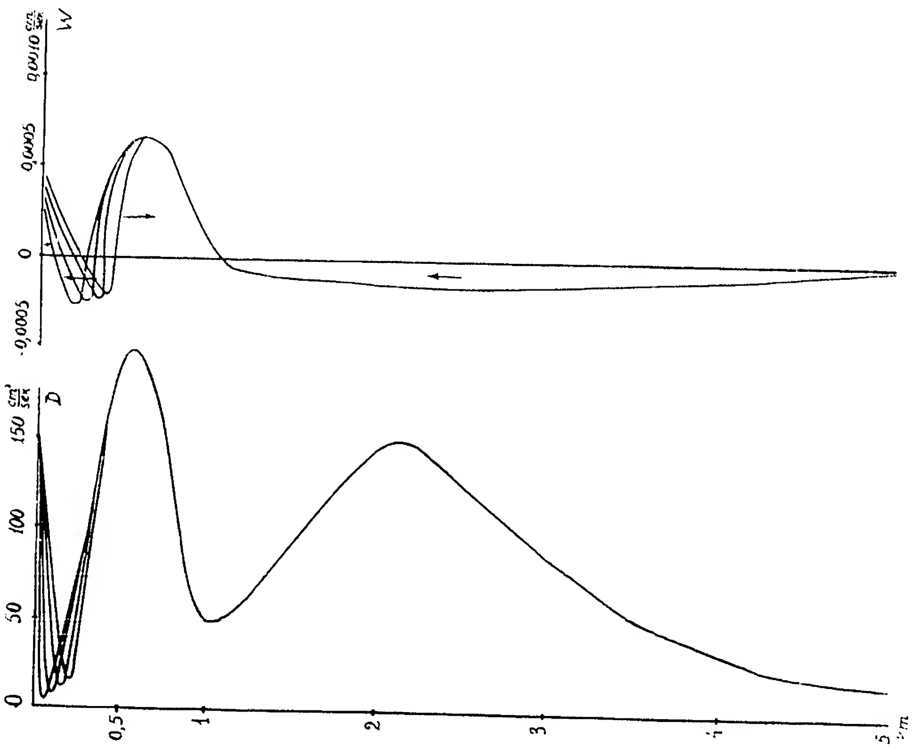

Fig. 1

766